

# European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

## COST Action TD1105

### INTERNATIONAL WG1-WG4 MEETING on

### *New Sensing Technologies and Modelling for Air-Pollution Monitoring*

Institute for Environment and Development - IDAD

Aveiro, Portugal, 14 - 15 October 2014

Action Start date: 01/07/2012 - Action End date: 30/06/2016 - Year 3: 2014-15 (*Ongoing Action*)

## HEALTH AND INDOOR ENVIRONMENT IN ELDERLY CARE CENTERS

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# BACKGROUND (I)

- The mean age of the European population is rising and the percentage of adults aged 65 years and older is projected to INCREASE FROM 16% IN 2000 TO 20% IN 2020 (Adan O., 2006).
- It has been estimated that OLDER PERSONS SPEND ABOUT 19-20 HOURS PER DAY INDOOR (WHO, 2003).



- Moreover, ELDERLY CARE HOMES HAVE THE POTENTIAL TO INFLUENCE PEOPLE'S LIVES socially, physically and psychologically (Bradshaw S., 2012).



# BACKGROUND (II)

- This is projected to have A MAJOR IMPACT ON THE DELIVERY OF HEALTH CARE, particularly ACUTE AND EMERGENCY SERVICES (Yim et al., 2009).
- The older people require significantly more emergency care resources compared to younger adults due to a decline in immune defences and respiratory function, resulting in a HIGHER PREDISPOSITION TO RESPIRATORY INFECTIONS (Bentayeb et al., 2013).
- Such conditions ARE HIGHLY PREVALENT, MULTIFACTORIAL, AND ASSOCIATED WITH MULTIPLE COMORBIDITIES AND POOR OUTCOMES, such as increased disability and decreased quality of life (Cigolle et al., 2007).

# BACKGROUND (III)

- Indoor air quality (IAQ) is a key indoor factor that might affect comfort, health and occupants' performance, PARTICULARLY IN SUSCEPTIBLE INDIVIDUALS SUCH AS ELDERLY.
- This population is particularly at risk of detrimental effects from pollutants, EVEN AT LOW CONCENTRATIONS, due to
  - REDUCED IMMUNOLOGICAL DEFENCES AND MULTIPLE UNDERLYING CHRONIC DISEASES.
  - AMOUNT OF TIME SPENT INDOORS (LONG EXPOSURE PERIODS).



- As a result, the STUDY OF IAQ IN THE ELDERLY POPULATION IS BECOMING AN IMPORTANT ISSUE TO BE ADDRESSED BY CLINICAL RESEARCH.

# PROJECT RESEARCH AIM (I)

- The aim of GERIA project is to CARRY OUT A RISK ASSESSMENT involving:
  - IDENTIFICATION OF MULTIPLE FACTORS potentially affecting HEALTH AND QUALITY OF LIFE;
  - QUANTIFICATION OF HUMAN EXPOSURE to pollutants, and
  - EVALUATION OF THE INDIVIDUAL'S RESPONSE to these stimuli.





# PROJECT RESEARCH AIM (II)

- The results of this project will:
  - contribute to the UNDERSTANDING OF HEALTH EFFECTS DUE TO INDOOR ENVIRONMENT VARIABLES, and
  - IMPROVE THE HEALTH OF OUR ELDERLY population.

**We believe that this program will be able to develop innovative strategies which, with relatively simple measures, could provide health benefits to elderly care centers residents.**

# PROJECT RESEARCH TEAM & FUNDING



**FCT** Fundação para a Ciência e a Tecnologia  
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA



# PROJECT STUDY DESIGN & SAMPLE (I)

## 1st Phase

22 ECC Porto

33 ECC Lisbon

### BUILDING CHARACTERIZATION

- Type of building construction
- Thermal isolation of the building
- Characteristics of building envelope
- Ventilation system
- Materials used for finishing
- Use of gas burning appliances that could influence the IAQ
- Evidences of dampness and mould at the building envelope
- Ventilation practices of the occupants

### HEALTH AND QUALITY OF LIFE QUESTIONNAIRES

- WHOQOL-BREF Questionnaire
- BOLD Questionnaire
- Mini Mental State Examination
- Geriatric Depression Scale GDS-15

## 2nd Phase

20 ECC Porto and Lisbon

### INDOOR AIR QUALITY ASSESSMENT

(AUTUMN/WINTER-SPRING/SUMMER)

- PM10 (INDOOR/OUTDOOR)
- PM2.5 (INDOOR/OUTDOOR)
- Formaldehyde (INDOOR)
- Total Volatile Organic Compounds (INDOOR/OUTDOOR)
- Carbon Dioxide (INDOOR/OUTDOOR)
- Carbon Monoxide (INDOOR/OUTDOOR)
- Temperature (INDOOR/OUTDOOR)
- Relative Humidity (INDOOR/OUTDOOR)
- Bacteria (INDOOR/OUTDOOR)
- Fungi (INDOOR/OUTDOOR)
- Thermal Comfort Indexes (INDOOR)

### CLINICAL TESTS

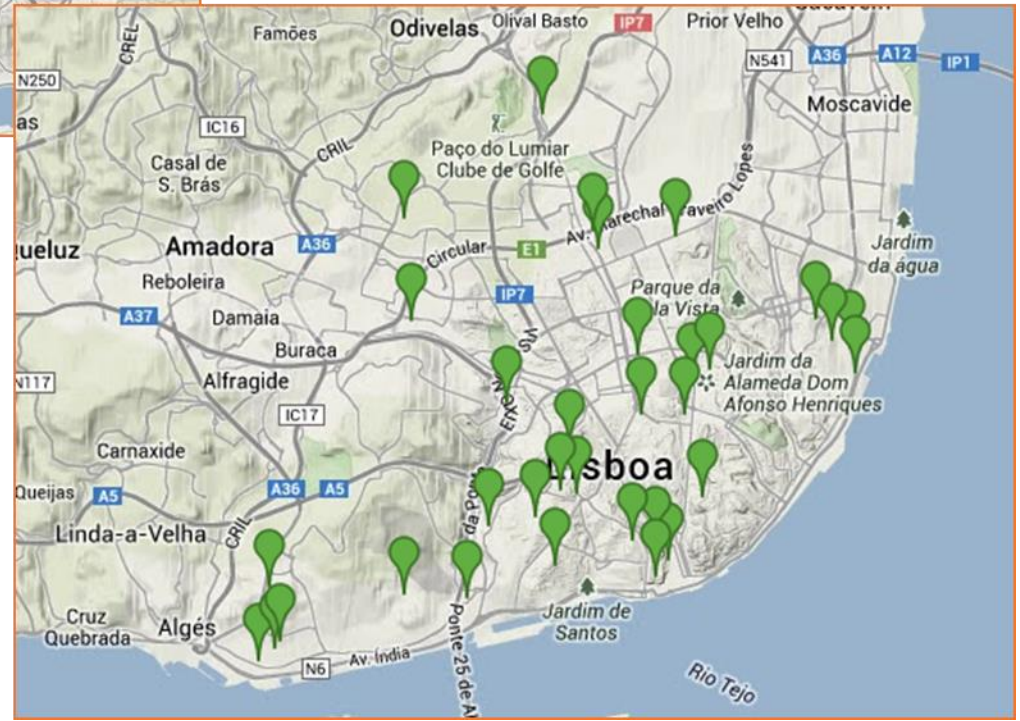
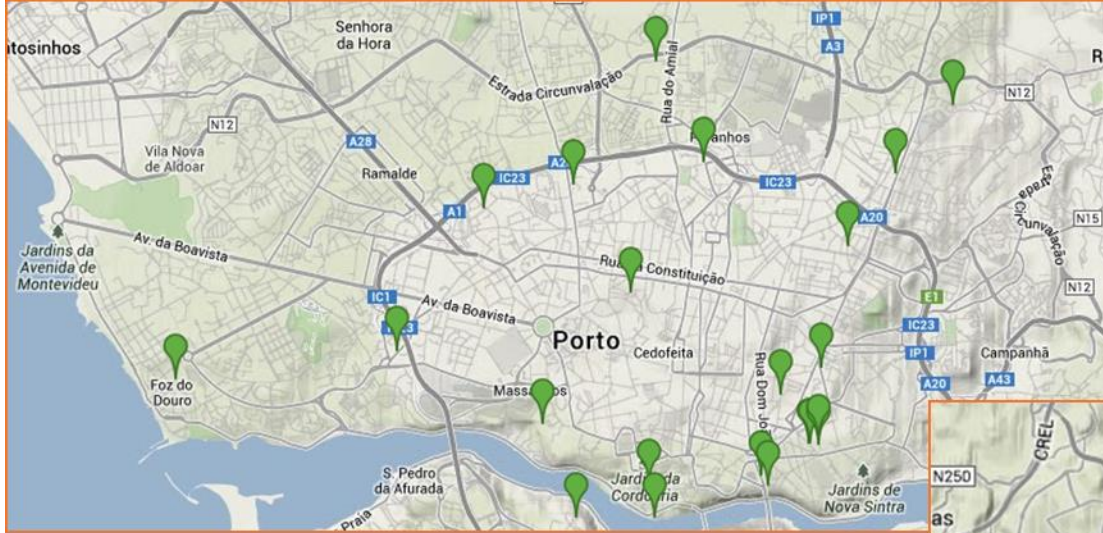
- Nasopharyngeal swabs for virus characterization
- Exhaled breath condensate
- Spirometry

### VENTILATION ASSESSMENT

- Tracer Gas Technique PFT
- Ventilation modeling



# PROJECT STUDY DESIGN & SAMPLE (II)





# STUDY CASE DESIGN & SAMPLE

- This study explored the IMPACT OF ENVIRONMENTAL VARIABLES IN 22 ELDERLY CARE CENTERS (ECC) LOCATED IN PORTO (41N11.8W36), Portugal.
- These areas were assessed for INDOOR ENVIRONMENTAL QUALITY contaminants from November 2011 until August 2013 :
  - CHEMICAL
    - CO<sub>2</sub>, CO, TVOC, Formaldehyde, PM<sub>10</sub>, PM<sub>2.5</sub>
  - BIOLOGICAL
    - Total bacteria and Fungi.
  - PHYSICAL (THERMAL COMFORT)
    - PMV Predicted Mean Vote
    - PPD Predicted Percent of Dissatisfied People

# STUDY CASE METHODS

n = 22



n = 143 (21 ECC)



- WINTER & SUMMER season IAQ Assessment
- 141 ROOMS assessed within dining rooms, drawing rooms, medical offices and bedrooms, including the bedridden subgroup
- OUTDOOR MONITORING for comparison
- BUILDING Characterization QUESTIONNAIRE
- STANDARDIZED PORTUGUESE VERSION OF BOLD (Burden of Obstructive Lung Disease) Questionnaire from September 2012 to April 2013 (all participants  $\geq 65$  years, live in the ECC for more than 2 weeks).

Caracterização dos edifícios: Características Construtivas do Edifício e Manutenção do Ambiente Interior

1.1 CARACTERIZAÇÃO DO EDIFÍCIO

1.2 MANUTENÇÃO DO AMBIENTE INTERIOR

GERIA

QUEIXAS RESPIRATORIAS (BOLD)

Vamos agora fazer de questões que são essencialmente sobre o seu peito.

12. Costuma ter TOSSE, habitualmente?  Não  Sim

13. Costuma tossir 4 a 6 vezes ao dia, em 4 ou mais dias da semana?  Não  Sim

14. Costuma tossir dessa forma na maioria dos dias, durante 3 ou mais meses do ano?  Não  Sim

15. Desde há quantos anos tem esta tosse?  anos  <2  2 a 5  >5

16. Costuma sofrer de EXPECTORAÇÃO (CATARRO) do seu peito?  Não  Sim

17. Costuma expectorar dessa maneira pelo menos 2 vezes ao dia, em 4 ou mais dias da semana?  Não  Sim

18. Costuma expectorar dessa forma, na maioria dos dias, durante 3 ou mais meses consecutivos do ano?  Não  Sim

19. Desde há quantos anos tem essa expectoração?  anos  <2  2 a 5  >5

20. Já alguma vez teve um ataque de PIERA no peito (SILVOS NO PEITO) que o tenha feito sentir dificuldade em respirar?  Não  Sim

21. Que idade tinha quando teve o primeiro ataque de pieira no peito?  anos

22. Já teve 2 ou mais episódios de pieira?  Não  Sim

23. Já alguma vez pieira nos últimos 12 meses?  Não  Sim

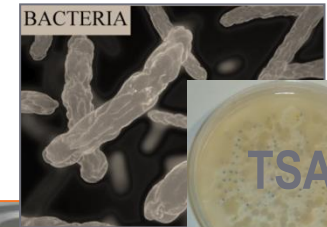
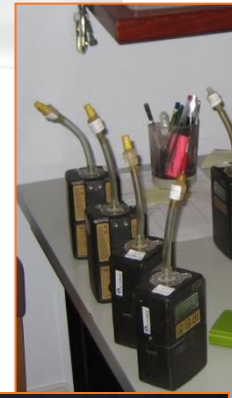
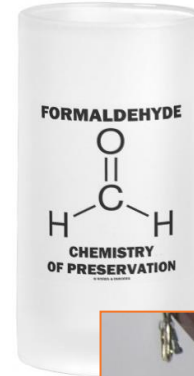
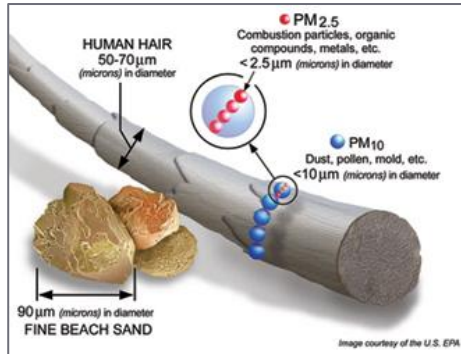
24. Tive alguma vez pieira nos últimos 12 meses?  Não  Sim

25. Tem LIMITAÇÕES DO ANDAR por DIFICULDADE EM RESPIRAR (FALTA DE AR), por outra situação não relacionada com a tosse e o catarro?  Não  Sim

26. Se Sim, especifique:

27. Costuma sentir-se atrapalhado pela falta de ar quando anda mais depressa ou quando sobe uma pequena inclinação?  Não  Sim

# IAQ ACTIVE SAMPLING METHODS



naked eye count

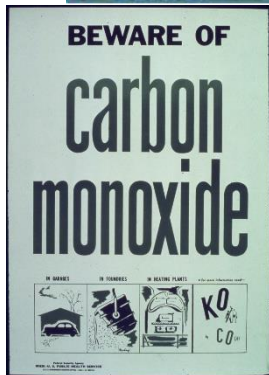


# IAQ DIRECT READING METHODS

TC indexes following ISO 7730:2005

PMV Predicted Mean Vote

PPD Predicted Percent of Dissatisfied People



*moderate environments* (class C – Comfort standard)

'Homogeneous' and steady-state environment  
tested according ISO 7726:2005 specifications  
with TSI 8386A-M-GB thermo-anemometer



MATLAB® Software

**Delta OHM HD32.1**

0.60 meters above the floor (sitting - abdomen level)

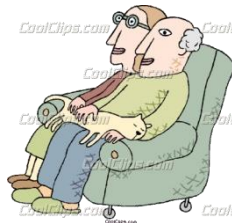
25 minutes EQUIPMENT STABILIZATION in each room

10 minutes MEASUREMENTS

**METABOLIC RATE** (Table B.1 - Annex B): 1.0 met (seated, relaxed)

**CLOTHING INSULATION** (TABLE C.1 – ANNEX C): 1 *clo* Summer

1.3 *clo* Winter



# RESULTS ECC BUILDING CHARACTERIZATION

Table 1. Distribution of ECCs by building characteristics (n = 22)

BUILDING CHARACTERISTICS	n	%
ADAPTED TO ECC	14	<b>66</b>
WALLS		
BRICKWORK	6	30
STONE MASONRY	11	49
BOTH	5	22
WITH ROOF & WALLS INSULATION	6	<b>30</b>
VENTILATION TYPE		
NATURAL (ONLY)	3	13
MIXED VENTILATION	19	87
HEATING		
CENTRAL HEATING (CH)	12	53
AUTONOMOUS DEVICES (AD)	9	43
CH + AD	1	4
WINDOWS		
WITH SEALANTS	13	43
DOUBLE-PANE GLASS	3	13
SINGLE-PANE GLASS	19	87
BUILDING PATHOLOGIES		
CONDENSATIONS + INFILTRATIONS	13	<b>61</b>
CLEAR	9	39

# RESULTS IAQ CHEMICAL PARAMETERS

Table 2. ECC Indoor/Outdoor Air Quality: Descriptive statistics by Season (part 1)

	Indoor		Outdoor		References		
	N	Mean [Min-Max]	N	Mean [Min-Max]	International	National	
PM <sub>10</sub> (mg/m <sup>3</sup> )	SUMMER	139	0.066 [0,02 – 1.73]	24	0.05 [0.02 – 0.25]	0.15 <sup>a)</sup>	0.05 <sup>d)</sup>
	WINTER	138	0.067 [0.02 – 0.43]	24	0.06 [0.02 – 0.21]		
PM <sub>2.5</sub> (mg/m <sup>3</sup> )	SUMMER	120	0.09 [0.02 – 2.12]	20	0.05 [0.02 – 0.18]	0.035 <sup>a)</sup>	0.025 <sup>d)</sup>
	WINTER	119	0.06 [0,02 – 0.86]	20	0.05 [0.02 – 0.29]		
TVOC (mg/m <sup>3</sup> )	SUMMER	129	0.11 [0.01 – <b>2.53</b> ]	22	0.17 [0.01 – 2.6]	0.2 <sup>b)</sup>	0.6 <sup>d)</sup>
	WINTER	137	0.13 [0.01 – <b>0.93</b> ]	20	0.04 [0.01 – 0.3]		
Formaldehyde (mg/m <sup>3</sup> )	SUMMER	77	0.002 [0.0002 – 0.06]	-	0.1 <sup>c)</sup>	0.1 <sup>d)</sup>	
	WINTER	84	0.008 [0.0002 – <b>0.32</b> ]				

a) Environmental Protection Agency (2012); b) European Collaborative Action (1997); c) World Health Organization (2010); d) Ordinance 353-A/2013.

# RESULTS IAQ CHEMICAL PARAMETERS

Table 2. ECC Indoor/Outdoor Air Quality: Descriptive statistics by Season (part 2)

	Indoor		Outdoor		References		
	N	Mean [Min-Max]	N	Mean [Min-Max]	International	National	
CO <sub>(mg/m<sup>3</sup>)</sub>	SUMMER	137	0.7 [0.1 – 7.1]	24	1.3 [0.1 – 7.7]	10 <sup>e)</sup>	10
	WINTER	137	0.6 [0.1 – 3.0]	24	0.9 [0.1 – 3.5]		
CO <sub>2</sub> (mg/m <sup>3</sup> )	SUMMER	137	786 [538 – <b>2313</b> ]	24	590 [384 – 893]	1300 <sup>f)</sup>	2250
	WINTER	137	1125 [541 – <b>2697</b> ]	24	609 [516 – 879]		
Bacteria (CFU/m <sup>3</sup> )	SUMMER	137	329 [6 – <b>2282</b> ]	23	162 [24 – 616]	-	< outdoor (until 350 CFU/m <sup>3</sup> more)
	WINTER	133	258 [14 – <b>996</b> ]	23	89 [8 – 368]		
Fungi (CFU/m <sup>3</sup> )	SUMMER	132	305 [6 – 2224]	23	531 [20 – 3454]	500 <sup>g)</sup>	< outdoor
	WINTER	130	260 [18 – 2812]	22	208 [62 – 676]		

d) Ordinance 353-A/2013; e) World Health Organization (2010); f) Finnish Society of Indoor Air Quality in 'The Thade Report' (2004); g) World Health Organization (2009).



# RESULTS IAQ ASSESSMENT BY TYPE OF ROOM

Table 3. Indoor Air Quality Parameters: Descriptive statistics by Room & Season - part 1

(mg/m <sup>3</sup> )	Mean [Min-Max]				
	Dining Room	Drawing Room	Bedroom	Bedridden	Medical Office
PM <sub>10</sub>					
SUMMER	0.14 [0.02 – 1.7]	0.06 [0.02 – 0.32]	0.05 [0.02 – 0.35]	0.05 [0.02 – 0.17]	0.03 [0.02 – 0.05]
WINTER	0.07 [0.02 – 0.3]	0.07 [0.02 – 0.43]	0.07 [0.02 – 0.37]	0.05 [0.02 – 0.2]	0.05 [0.02 – 0.09]
PM <sub>2.5</sub>					
SUMMER	0.06 [0.02 – 0.3]	0.11 [0.02 – 1.39]	0.05 [0.02 – 0.26]	0.2 [0.02 – 2.1]	0.3 [0.02 – 0.6]
WINTER	0.06 [0.02 – 0.2]	0.08 [0.02 – 0.6]	0.06 [0.02 – 0.9]	0.03 [0.02 – 0.11]	0.04 [0.02 – 0.13]
TVOC					
SUMMER	0.1 [0.03 – <b>0.7</b> ]	0.13 [0.01 – <b>2.5</b> ]	0.12 [0.02 – <b>0.9</b> ]	0.04 [0.02 – 0.08]	0.06 [0.03 – 0.15]
WINTER	0.14 [0.01 – <b>0.7</b> ]	0.15 [0.03 – <b>0.9</b> ]	0.13 [0.02 – <b>0.8</b> ]	0.09 [0.03 – 0.3]	0.15 [0.02 – 0.2]
Formaldehyde					
SUMMER	0.002 [0.0002 – 0.02]	0.004 [0.0002 – 0.06]	0.0002 [0.0002]	0.004 [0.0002 – 0.03]	0.0002 [0.0002]
WINTER	0.002 [0.0002 – 0.02]	0.016 [0.0002 – <b>0.32</b> ]	0.008 [0.0002 – 0.3]	0.003 [0.0002 – 0.03]	0.007 [0.0002 – 0.04]

# RESULTS IAQ ASSESSMENT BY TYPE OF ROOM

Table 3. Indoor Air Quality Parameters: Descriptive statistics by Room & Season - part 2

	Mean [Min-Max]				
	Dining Room	Drawing Room	Bedroom	Bedridden	Medical Office
$\text{CO}_{(mg/m^3)}$					
SUMMER	0.7 [0.1 – 4.4]	0.6 [0.1 – 5.4]	0.8 [0.1 – 7.1]	0.9 [0.1 – 5.3]	0.5 [0.1 – 1.2]
WINTER	0.6 [0.1 – 2.3]	0.6 [0.1 – 2.6]	0.7 [0.1 – 3.0]	0.47 [0.1 – 1.9]	0.3 [0.1 – 0.8]
$\text{CO}_2_{(mg/m^3)}$ *					
SUMMER	938 [595 – <b>2313</b> ]	833 [553 – 1583]	728 [538 – 1221]	689 [543 – 984]	718 [640 – 842]
WINTER	1323 [563 – <b>2374</b> ]	1157 [541 – 2009]	1001 [579 – <b>2697</b> ]	1143 [678 – 1590]	1243 [581 – 2113]
Bacteria $(\text{CFU/m}^3)$ *					
SUMMER	427 [92 – <b>1414</b> ]	411 [36 – <b>2282</b> ]	252 [6 – <b>1386</b> ]	269 [58 – <b>1052</b> ]	342 [84 – <b>650</b> ]
WINTER	298 [14 – <b>996</b> ]	293 [44 – <b>838</b> ]	210 [20 – <b>630</b> ]	262 [40 – <b>618</b> ]	343 [30 – <b>820</b> ]
Fungi $(\text{CFU/m}^3)$					
SUMMER	412 [8 – <b>2224</b> ]	269 [38 – <b>1010</b> ]	290 [6 – <b>1128</b> ]	251 [34 – <b>640</b> ]	387 [36 – <b>824</b> ]
WINTER	<b>366</b> [38 – <b>2812</b> ]	<b>259</b> [26 – <b>784</b> ]	<b>241</b> [18 – <b>1218</b> ]	<b>218</b> [18 – 502]	171 [80 – 284]

# RESULTS IAQ OVERALL

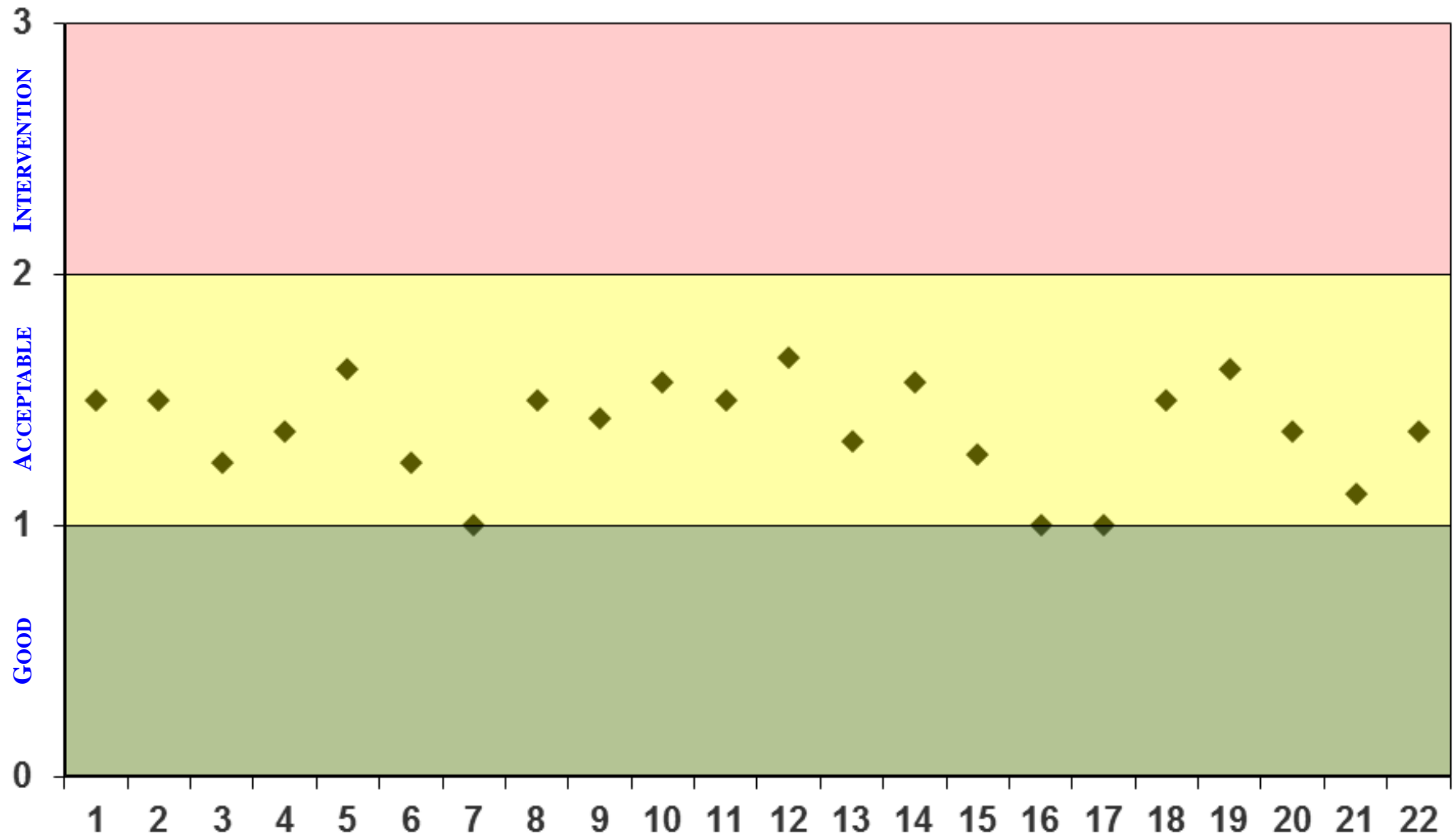


Figure 1. Overall rating of ECCs indoor air quality

# RESULTS IAQ OVERALL

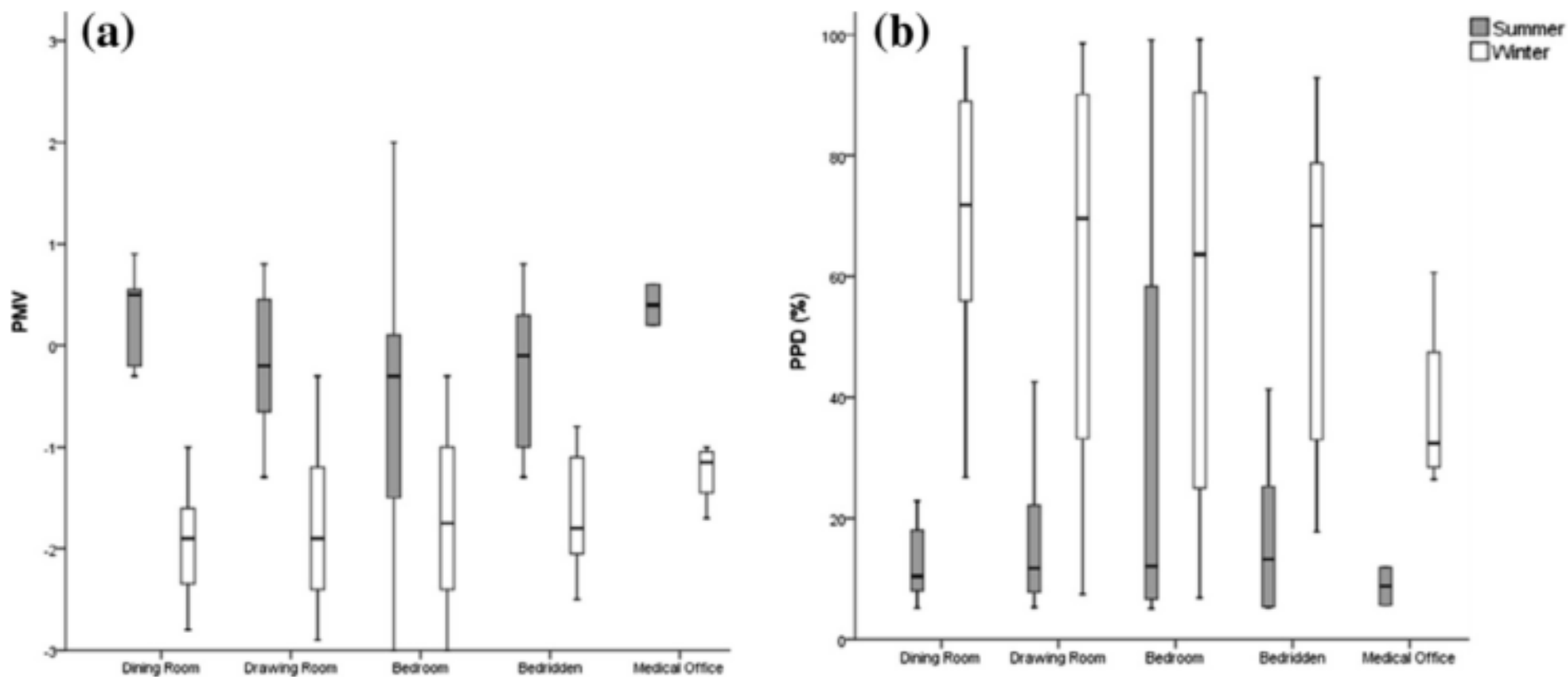


Figure 2. (a) PMV index by room and season, (b) PPD index (%) by room and season (mean of the 22 ECCs)

# RESULTS BUILDINGS VS. IAQ ASSESSMENT

Table 4. Building characteristics in the indoor environmental evaluation

Buildings Variables	Parameters				Bacteria	Fungi	CO	CO <sub>2</sub>	Temp.	RH	PPD	PMV
	PM <sub>10</sub>	PM <sub>2.5</sub>	TVOC	HCHO								
Adapted to ECC		Green		Orange		Green	Orange		Green	Orange	Orange	Orange
Building occupation					Orange	Green			Green	Green	Green	Green
Sources of pollution			Orange	Green		Green			Green			
Walls			Orange		Blue				Blue	Blue		
Insulation		Blue	Orange	Green		Orange	Orange		Green	Green	Green	Orange
Roof lining					Blue	Orange	Green		Green	Green	Blue	Orange
Ventilation type		Blue			Blue	Blue				Green		
Heating ventilation		Orange	Orange	Orange	Green		Orange		Green	Green	Green	Green
Building pathologies		Green			Green	Green	Blue					
Windows type	Orange				Blue	Green			Green	Green	Blue	Green
Sealants					Green			Green				
Type sealants	Orange		Green		Green	Blue		Green				
Windows frames	Orange		Orange	Orange		Orange	Blue	Blue	Green		Blue	Blue
Glass type			Orange						Green		Orange	
Flooring		Green	Green	Orange		Blue			Green	Green		

Significant differences by building variable and environmental evaluation: Green p < 0.001; Orange p < 0.01; Blue p < 0.05

# RESULTS ELDERLY POPULATION

Table 5. General descriptive of the elderly subjects (n = 143) and self-perceived health and quality of life status

	n (%)
GENDER	
Female	121 (84.6)
Male	22 (15.4)
AGE GROUP	
[65-75]	19 (13.2)
[76-85]	57 (39.9)
> 85	67 (46.9)
YEARS LIVING IN THE ECC	
≤ 1 year	37 (25.9)
[2-10]	83 (58.0)
> 11	23 (16.1)
OVERALL QUALITY OF LIFE PERCEPTION AND SATISFACTION WITH HEALTH *	
≤ 63	88 (62.9)
> 63	52 (37.1)
DEMENTIA (MMSE QUESTIONNAIRE) **	57 (40.4)
DEPRESSION (GDS15 QUESTIONNAIRE) ***	49 (35.3)
IMPAIRED PHYSICAL MOBILITY AND BEDRIDDEN	85 (61.2)
SELF-PERCEIVED HEALTH STATUS (SICKNESS)	52 (40.3)



**AVERAGE: 84**  
**MINIMUM: 67**  
**MAXIMUM: 103**

# RESULTS ELDERLY POPULATION



In elderly respondents:

- COUGH (23%) AND SPUTUM (12%) were the major respiratory symptoms,
- ...and ALLERGIC RHINITIS (18%) the main self-reported illness.
- HEART TROUBLES were reported by 37% residents.
- Symptoms of WHEEZING (11%) in the last 12 months and ASTHMA DIAGNOSIS (8%) were more common in FEMALES,
- ... as opposed to symptoms SHORTNESS OF BREATH (5%) AND SPUTUM (4%), MORE FREQUENT IN MALES.
- SMOKING HABITS, both past and present, were MORE FREQUENT IN MEN (12%).

In the ECC that participated in this study, allergic rhinitis was the main self-reported illness. High levels of PM10 were associated with a 3-fold odds of allergic rhinitis (OR = 2.9, 95% CI: 1.1 – 7.2).

# FINAL REMARKS (I)

- Overall PM<sub>10</sub> mean concentration WAS ABOVE NATIONAL REFERENCE LEVELS (0.05 MG/M<sup>3</sup>) IN BOTH SEASONS.
- PM<sub>2.5</sub> mean concentration of the 22 ECC WAS ABOVE NATIONAL (0.025 MG/M<sup>3</sup>) AND INTERNATIONAL (0.035 MG/M<sup>3</sup>) REFERENCE LEVELS IN BOTH SEASONS.
- Peak values of TVOC, CO<sub>2</sub>, BACTERIA AND FUNGI EXCEEDED THE REFERENCE LEVELS.
- TVOC, Bacteria, CO and CO<sub>2</sub> SHOWED SIGNIFICANTLY HIGHER INDOOR LEVELS COMPARED TO OUTDOOR, IN BOTH SEASONS.



# FINAL REMARKS (II)

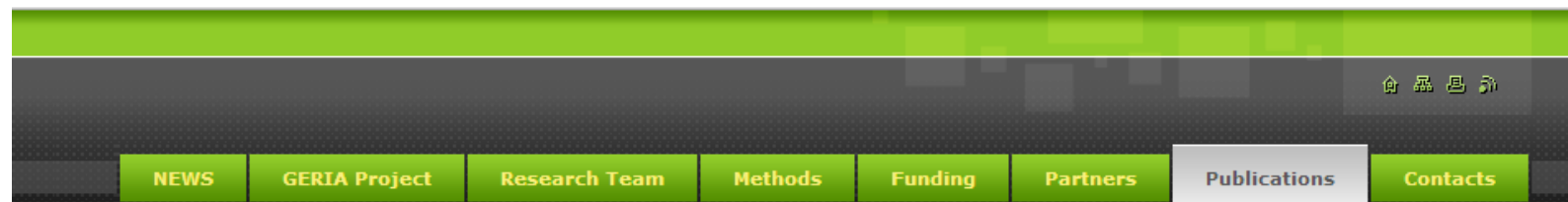
- Indoor PM<sub>10</sub>, TVOC, Bacteria and CO<sub>2</sub> PRESENT SIGNIFICANT DIFFERENCES BETWEEN SEASONS (p < 0.01).
- TVOC, bacteria and CO<sub>2</sub> show SIGNIFICANT VARIATION BETWEEN ECC ROOMS (p < 0.01).
- The WINTER PMV INDEX IS BELOW REFERENCES AND BETWEEN THE 'SLIGHTLY COOL' (-1) AND 'COOL' (-2) points in the thermal sensation scale, which may potentiate respiratory tract infections.
- PPD and PMV indices SHOW SIGNIFICANT DIFFERENCES BY ROOM AND BY SEASON (p < 0.01).

# FINAL REMARKS (III)

- Indoor environment HAVE A POTENTIAL INFLUENCE IN CHRONIC RESPIRATORY SYMPTOMS ON OLDER PEOPLE LIVING IN ECC.
- Self-perceived symptoms questionnaires HAVE SOME LIMITATIONS WHEN APPLIED TO OLDER PEOPLE WITH PHYSICAL AND COGNITIVE IMPAIRMENTS. These results need to be confirmed in future studies.
- Adequate measures:
  - LOCAL EXHAUST VENTILATION SYSTEMS near cooking and gas burning devices
  - DAILY SLIGHTLY MOIST CLEANING of the rooms surfaces would reduce particle accumulation and re-suspension.
  - Simple measures such as INSULATING CEILINGS, WALLS AND WINDOWS, MAINTAINING NATURAL AND PASSIVE VENTILATION, could prevent low indoor temperatures and discomfort, especially on winter season.

# MORE INFORMATIONS (I)...

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**GERIA - Geriatric study in Portugal on Health Effects of Air Quality in Elderly Care Centers**

 [geriastudy@gmail.com](mailto:geriastudy@gmail.com)



## PUBLICATIONS

### • ARTICLES

- Livia Aguiar, Ana Mendes, Cristiana Pereira, Paula Neves, Diana Mendes, João Paulo Teixeira. 2014. Biological Air Contamination in Elderly Care Centers: GERIA Project. Journal of Toxicology and Environmental Health. Accepted.
- Ana Mendes, Stefano Bonassi, Livia Aguiar, Cristiana Pereira, Paula Neves, Susana Silva, Diana Mendes, Luís Guimarães, Rossana Moroni, João Paulo Teixeira. Indoor Air Quality and Thermal Comfort in Elderly Care Centers. Submitted in 2013 - Under Review.
- [Ana Mendes, Cristiana Pereira, Diana Mendes, Livia Aguiar, Paula Neves, Susana Silva, Stuart Batterman & Joao Paulo Teixeira. 2013. Indoor Air Quality and Thermal Comfort - Results of a Pilot Study in Elderly Care Centers in Portugal. Journal of Toxicology and Environmental Health, Part A \(2013\). DOI:10.1080/15287394.2013.757213.](#)

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## INDOOR AIR QUALITY AND THERMAL COMFORT—RESULTS OF A PILOT STUDY IN ELDERLY CARE CENTERS IN PORTUGAL

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## BIOLOGICAL AIR CONTAMINATION IN ELDERLY CARE CENTERS: GERIA PROJECT

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## Indoor air quality and thermal comfort in elderly care centers

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